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Alternative Version of Chiral Color as Alternative to the Standard Model

Paul H. Frampton*

Department of Physics and Astronomy, University of North Carolina, Chapel Hill, NC 27599-3255.†
Institute for the Physics and Mathematics of the Universe, University of Tokyo, Kashiwa, Chiba 277-8568, Japan.

Abstract

In a variant of chiral color with the electroweak gauge group generalized to $SU(3)_L \times U(1)$ anomaly cancellation occurs more readily than in the $SU(2)_L \times U(1)$ case. Three families are required by anomaly cancellation and the top family appears non-sequentially.

*frampton@physics.unc.edu
†permanent address

Introduction

Any small discrepancies from the standard model of particle theory merit further study to point the way towards an extension of the model. One such possible discrepancy is the motivation for the present Letter.

Recent experimental data on top production at FermiLab [1] give hints about a departure from the predictions of QCD. One possible interpretation, *e.g.* [2], is in terms of an axigluon in the s-channel of the quark-antiquark annihilation. Therefore it is worth re-examining that theory from the 1980's with a view to enunciating any additional predictions for experiment.

Chiral color represents one path of model building beyond the standard model [3] [#3]. The color symmetry of QCD results from symmetry breaking of a $SU(3)_L \times SU(3)_R$ gauge symmetry at TeV scales and leads to the prediction of a color octet of massive axigluons.

Searches in hadron colliders have led to a lower limit on the axigluon mass of at least 1 TeV [5].

More recently, a small (2σ) effect in the $t\bar{t}$ forward-backward asymmetry at the Tevatron [1] has prompted some analysis in terms of axigluon, as well as other possible new colored particles [2]. While this experimental anomaly has too large a statistical error to be taken as firmly based, it does lead to a possible re-examination of the chiral color model.

Here we show that, by generalizing the original version [3], one can arrive at a simplified anomaly cancellation which requires the existence of three families.

Anomalies of Original Chiral Color.

First recall that the original chiral color used the gauge group

$$SU(3)_{CL} \times SU(3)_{CR} \times SU(2)_L \times U(1)_Y \tag{1}$$

with each family assigned to the reducible representation

(3, 1; 2, 1/3) + (1, 3; 2, 1/3)
+ (3*, 1; 1, -4/3) + (3*, 1; 1, 2/3)
+ (1, 3*;1, 2/3) + (1, 3*; -4/3)
+ (1, 1; 2, -1)

[#3] Precursors appeared in [4].

+ (1, 1; 1, +2)

This model needed additional fermions to cancel anomalies because for the seven potential triangle anomalies for each sequential family:

(I) Y^3 fails.
(II) $Y3^2_{CL}$ cancels.
(III) $Y3^2_{CR}$ cancels.
(IV) $Y2^2_L$ fails.
(V) 3^3_{CL} cancels.
(VI) 3^3_{CR} cancels.
(VII) Y cancels.

Resolving the anomaly cancellation for (I) and (IV) led to a variety or proposals for adding further colored chiral fermion [3]

Anomalies of Alternative Chiral Color.

The gauge group in the generalization will be [#4]

$$SU(3)_{CL} \times SU(3)_{CR} \times SU(3)_L \times U(1)_X \tag{2}$$

The 1st family is assigned as follows

LH quarks (3, 1; 3, -1/3)
RH quarks (1, 3*; 1, -2/3) + (1,3*; 1, 1/3) + 1/3) + (1, 3*;1, 4/3)
leptons (1, 1; 3*, 0)

and the second family is

LH quarks (1, 3; 3, -1/3)
RH quarks (3*, 1; 1, -2/3) + (3*, 1; 1, 1/3) + 1/3) + (3*, 1 ;1, 4/3)
leptons (1, 1; 3*, 0)

while the third family is

LH quarks (3, 1; 3*, 2/3)
RH quarks (3*, 1; 1, -5/3) + (3*, 1; 1, -2/3) + (3*, 1; 1, 1/3)
leptons (1, 1; 3*, 0)

This introduces an anomaly (VIII) $(3_L)^3$ beyond the analogs of (I) through (VII) for the original chiral color model where there is no $(2_L)^3$ anomaly. With the assigmements given above *all* anomalies (I) through (VIII) cancel.

[#4] This is related to models in [6].

What is remarkable is that this alternative chiral color succeeds to cancel the analogs of all the seven anomalies (I) - (VII) above, plus the new anomaly (VIII) 3_L^3; also *e.g.* the X^3 anomaly requires three families for cancellation.

Higgs sector

In order to break chiral color to QCD we require a VEV of a bi-triplet scalar

(3, 3*; 1, 0)

while to break the electroweak group $SU(3)_L \times U(1)_X \rightarrow SU(2)_L \times U(1)_Y \rightarrow U(1)_{EM}$ requires the scalars

(1, 1; 3, 0) + (1, 1; 3, 1)

whose VEVs can provide mass to all the quarks and charged leptons.

Discussion

Partially because of the hints from $p\bar{p} \rightarrow t\bar{t}$ (and they are no more than hints) that new colored objects may be necessary, it seems worth re-examining models which have this feature.

The present alternative to chiral color provides a novel three-family anomaly cancellation and places the third family containing the t-quark aymmetrically with respect to lighter quarks.

The present alternative version predicts additionally the bilepton gauge bosons discussed in [6] necessary for the simpler arrangement of anomaly cancellation, so that there are gauge bosons beyond those of the standard model in both the strong and electroweak sectors separately.

It will be interesting to see whether the effects reported in [1] will survive as the experiments acquire higher statistics. Beyond that, there is the question whether additional gauge bosons as predicted here in the electroweak sector will be discovered.

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